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Section A

High level controls at RHIC +

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We report on the software tools and techniques in development to ensure that the commissioning and operations teams for RHIC have access to high level analysis, diagnosis, modelling and control functions early in the start up of the machine. The first tests will be for the sextant test in mid-1995.

1. Introduction

The RHIC (Relativistic Heavy Ion Collider) at Brookhaven National Laboratory is intended to start physics operation in 1999 to collide ions of species ranging from protons to gold. A test of the injection lines with a beam from the AGS (Alternating Gradient Synchrotron) into $\frac{1}{12}$ of one of the superconducting rings is scheduled for the end of 1995. The RAP (RHIC Accelerator Physics) group is charged with beam physics aspects and with commissioning and initial operation of the accelerator (as opposed to the individual systems such as magnet power supplies or RF, which are the responsibility of the separate engineering groups). The group has started several "vertical integration" projects to design and implement systems to pull together the efforts of the engineering groups and add the integration framework necessary for effective and timely commissioning and operation. These projects have a strong bearing on many details of the accelerator systems, especially the controls. We describe here the tools and techniques we are exploring to clarify what is need from the control system. As we intend to produce systems useful for the early beam test, we must produce working prototypes, not just paper specifications.

2. Techniques

We are applying a series of top-down analysis techniques to augment the "single system" methods of the engineering groups. This is to provide a framework in which our projects can be built, tested and modified while their place in the broader context is clarified. Due to the short time until the first beam tests and to lack of manpower, we cannot allow the use of these formal techniques to move too far from reality; we must exercise the abstract as quickly as possible. On the other hand, we must not succumb to ad-hoc fixes for each problem as it arises.

The design sequence we have started is described, for example, in ref. [1]. Briefly, the sequence is to build an entity-relationship model [2] of the data in and around the system being considered. These statically-defined data lead to identification of how the data change and thence to a data-flow diagram describing the processes involved in the system and how data moves amongst them. Finally, the sequence in which these processes occur is analyzed to give a control-flow specification.

Due to the nature of these projects – they have real short- and medium-term goals which affect the RHIC project as a whole – implementation of prototype components is under way in parallel with the formal analysis. These prototypes may be throw-away or may serve as the basis for operational code for the sextant test. To try to maximize the future usefulness of this work, we are encouraging an Object-Oriented approach to implementation, not just within programs and libraries but also between programs, by using the data description and sequencing tools described below.

3. Tools

The bare environment in which we work is UNIX and as far as possible is non-proprietary. C and C++ are the preferred languages, although FORTRAN is found, especially in the machine optics codes such as TEAPOT [3]. C++ will be used in the front-end supervisory comput-

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ers, which are VME cards running the VxWorks operating system. This builds upon previous experience of the controls group and should ease the connection between front end and console computers. Effort is being made to ensure that, at least at the console level, a heterogeneous computer network is possible.

Compilers and other tools from the Free Software Foundation are used almost exclusively, although a commercial relational database manager, Sybase, is used to the extent that even input files for machine lattice design codes are generated from the primary optics information resident in the database.

Free software from the Lawrence Berkeley Laboratory is used in data design and data query. Erdraw [4] automates data design based on entity-relationship modelling and can generate SQL script to implement a designed data structure on various commercial database managers, including Sybase. QST uses the meta-database created by Erdraw to provide a graphical database query interface [4].

ISTK (the Integrated Scientific Toolkit) [5] provides two tools to help to make modular the prototype components:

– Firstly, we use SDS (Self Description Standard) libraries and executables to ensure that data passed between programs is strongly typed and explicitly named. The description header of SDS also allows binary data to be converted between different machine architectures and greatly simplifies programmatic data access from and entry to the database manager. Using SDS, programs can be highly flexible in their input requirements; in the limit allowing data browsers and graphical tools to interpret and display arbitrary data structures.

– Secondly, Glish [6] is used to provide the control flow to connect separate programs. Glish is a language, C + + class library and executive to carry out high-level sequencing. Each program in a Glish sequence may generate and/or consume events: these events have values of arbitrary and strongly-typed data. SDS is used as the underlying description mechanism.

The routing of events in a given sequence is carried out by the Glish executive under control of a script describing the required connections. As Glish is a powerful language in its own right, event names may be changed and the data of event values manipulated within the script.

4. Applications

Several projects are currently under way, all in their early stages (about two months effort at the time of writing). The degree to which each project is vertically mixed varies, but so far each component of our planned approach has been exercised, from data design through high-level analysis codes to low-level data acquisition, including the following.

(1) Linear orbit correction in the AGS to RHIC transfer line is performed with 2-bumps (pairs of corrector/beam-position monitor pairs out of phase by 90°) at four important locations: extraction from the AGS, entrance to the 20° bend, entrance to the 90° bend and RHIC injection. An overlapping 3-bump RMS algorithm, clorb, is used to correct the orbit globally through the beamline. The current design corrects the linear orbit to 3–4 mm for typical 10^{-3} field errors and 0.1 mrad dipole errors. Application development is underway to integrate the correction schemes mentioned above with control tools. Collections of similarly typed instruments (monitors, correctors, etc.) will be available to the application programmer as C + + objects, naturally leading to a hierarchical description of the orbit correction process. To date, the high level code has been applied to calculated beam behavior, resulting in recommendations for additional instrumentation in the lines.

(2) Transverse beam profile measurements will be digitized by CCD cameras looking at thin phosphor-coated screens inserted into the beam at several locations in the transfer lines.

It is assumed that there will be negligible horizontal–vertical coupling in the extracted beam from the AGS, since there are no skew elements in the transfer lines. A verification of the assumption can be made, since the full 2-D data profile is available from the camera signal. Measurements can be made for each extracted bunch and the thin screens may allow simultaneous measurement at more than one location. The data from the camera will be digitized by a frame grabber and the complete two dimensional profile will be available for the top end application.

Sketching out such an application has shown the necessity for a reservation and permissions scheme, as there are a limited but configurable number of devices which are potentially damaging to the beam. We hope that early design and experience with such a scheme can grow into a system service.

(3) Beam studies are needed on the AGS to improve transition crossing in preparation for RHIC injection. This work is of interest to RAP both because high and reproducible injected beam quality is of vital importance to productive running and because RHIC heavy ion beams will also cross transition. RHIC will be the first superconducting machine to cross transition and the slow ramp rate imposed by the superconducting magnets will pose particular problems. So far, the integration studies on the AGS have digitized the longitudinal bunch profile for a full cycle (some 2.4 s at a frame rate of 1.5 kHz) and presented and made preliminary analyses on a workstation in close to real time, with mountain range and "movie" representations of the bunch movement available within 1 s or so of the end of beam. We intend to improve this integration of low-end data acquisition with high end presentation and analysis to provide a powerful tool for AGS studies and a prototype for similar systems for RHIC.

(4) The ramped interaction region quadrupoles of the

RHIC present a complex problem, as each ramp generator drives a power supply that may power more than one magnet and a given magnet may be powered by more than one supply. A simple control model of a magnet-and-power-supply pair is insufficient: the data model must show connections from the physics requirements for a given "beta squeeze" into an engineering model; the tables of currents required in the power supplies as a function of time into the squeeze. From this engineering model comes a hardware model which describes the tables in ramp generator cards, events sent on the broadcast timing system and so on. This project has concentrated to date on the generation of strength tables from optics calculations and on a data model at whose heart is a "Defined Device". As these entities may contain themselves, a hierarchical model can be built up to describe the interaction region quadrupole buswork. This information is needed to transform the entities in the "Physics Model" part of the data design into an "Engineering Model" and thence to a "Hardware Model".

In all these cases, it would be simpler at this stage to take a restricted view of the job, but it is the purpose of these projects to raise questions of wider relevance: the provision of a coherent model of how components fit and where they fit, identification of common services, performance needs, connectivity of databases and so on. By concerning themselves with such issues while being involved with real and pressing problems, the teams hope to help to define and implement a control structure designed with commissioning and operation in mind.

References

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[5] Further information and documentation may be obtained by email to one of the authors, salty@owl.rhic.bnl.gov.

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